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Canadian Science Advisory Secretariat
Science Response 2016/049

UPDATE TO THE ECOLOGICAL RISK ASSESSMENT OF GRASS CARP (*Ctenopharyngodon idella*) FOR THE GREAT LAKES BASIN: LAKE ONTARIO

Context

In 2014, Fisheries and Oceans Canada (DFO), through the Asian Carp Program, identified the need for a peer-reviewed binational ecological risk assessment of Grass Carp for the Great Lakes basin. This project was vetted through the Asian Carp Regional Coordinating Committee, coordinated by the Great Lakes Fishery Commission (GLFC) and included experts from the DFO, the GLFC, the U.S. Geological Survey (USGS) and the U.S. Fish and Wildlife Service (USFWS) as authors of the risk assessment. The process used for this ecological risk assessment followed guidance provided in the "*National Detailed-Level Risk Assessment Guidelines: Assessing the Biological Risk of Aquatic Invasive Species in Canada*" (Mandrak et al. 2012). This process serves to summarize the best available information and identify the relative risks posed to a specified area within a specified timeframe by a non-native species. The risk assessment document (Cudmore et al. 2017) contains the body of information used to develop the overall risk of Grass Carp for the Great Lakes basin, across all risk assessment elements, by consensus of the peer-review participants and, ultimately, the authors. It is the definitive science document of this process and includes science advice. The peer-review process followed the guidelines set out by the DFO Canadian Science Advisory Secretariat (CSAS) and met the requirements of the USGS Fundamental Science Practices.

The ecological risk assessment of Grass Carp for the Great Lakes basin (Cudmore et al. 2017) collected and presented information on historical arrivals and risks of Grass Carp to each of the Great Lakes given the information available up to the base assessment year of 2014. At the time, five Grass Carp had been reported from the Lake Ontario basin between 1985 and 2010 (Cudmore et al. 2017); this information helped inform the level of risk assigned to the Lake Ontario basin. After the risk assessment document was peer reviewed, but before it was approved for release, eight Grass Carp were captured in the Canadian waters of Lake Ontario in 2015, including six diploids. These captures are significant and may change the likelihood rankings and ecological consequences ratings for Lake Ontario in the risk assessment document, which may affect the scientific advice regarding the risk of Grass Carp to Lake Ontario. As a result, revision of the likelihood rankings and ecological consequences ratings for Lake Ontario prior to finalization and public release of the risk assessment document was deemed prudent by the risk assessment author team. However, the risk assessment document has already been peer reviewed and no further revisions are permitted. Therefore, a Science Response Report, acting as an addendum to the risk assessment document, was determined to be the appropriate course of action to incorporate this new and important information. The revised likelihood ranks and ecological consequence ratings for Lake Ontario captured in this document use the new baseline of November 2015 and should be considered as replacing the likelihood ranks and ecological consequence ratings for Lake Ontario in the binational Grass Carp risk assessment document (Cudmore et al. 2017). This Science Response Report was reviewed by all authors. Consideration of these captures in the risk assessment process

ensures effective scientific advice on the risk of Grass Carp to the Great Lakes basin is provided for managers in a timely manner.

This Science Response Report results from the Science Response Process of February 26, 2016 on the Update to the Ecological Risk Assessment of Grass Carp (*Ctenopharyngodon idella*) for the Great Lakes Basin: Lake Ontario.

Background

Lake Ontario: Grass Carp Captures in 2015

Beginning in 2014, the DFO Asian Carp Program initiated targeted early detection sampling for Asian carps in the Lake Ontario basin. This sampling effort was localized to four tributaries: Credit River, Etobicoke Creek, Humber River, and Jordan Harbour (Table 1, Figure 1). A total of 31 sites (Table 2) were sampled in these four tributaries using four gear types (Table 1). These gears cover both large-bodied and small fishes (i.e., juveniles). No Asian carps were captured in the Lake Ontario basin during the 2014 sampling season.

Figure 1. Collections (n=8) of Grass Carp in Lake Ontario and its watershed in 2015. All captures were of adult Grass Carp. The numbers next to the points represent the number of fish collected at that location.

Table 1. Grass Carp sampling effort in the Lake Ontario basin for 2014 and 2015 by DFO.

Gear Type	2014		2015	
	Number of Sites	Effort	Number of Sites	Effort
Mini fyke nets	11	236 hours	28	593 hours
Seine net	1	3 hauls	3	9 hauls
Tied-down gill nets	10	188 minutes	13	377 minutes
Trap nets	9	193 hours	23	474 hours
Electrofishing	-	-	27	19287 seconds
Trammel nets	-	-	4	292 minutes

Table 2. DFO Grass Carp sampling locations and effort in the Lake Ontario basin for 2014 and 2015.

Location	Number of Sites Sampled per Year	
	2014	2015
Credit River	13	27
Etobicoke Creek	1	-
Humber River	7	19
Jordan Harbour	10	49
Duffins Creek	-	2
Frenchman's Bay	-	4

In 2015, the DFO Asian Carp Program expanded on their 2014 early detection sampling efforts for Asian carps to include Duffins Creek and Frenchman's Bay, but Etobicoke Creek was eliminated as habitat was deemed unsuitable for Grass Carp and no surrogate species were detected. More sites were also sampled at Credit River, Humber River, and Jordan Harbour (Table 2). A total of 101 sites were sampled and six gear types employed (Table 1). While there was an increased sampling effort in 2015, only one Grass Carp (Jordan Harbour) was caught in August (diploid male Grass Carp in Jordan Harbour, Lincoln, Ontario) as a result of this effort (Table 3, Figure 1).

Table 3. Grass Carp capture data in Canadian waters of Lake Ontario for 2015.

	Capture Date	Location	Agency	Gear	Status	Ploidy	Sex	Age	Length (m)	Weight (kg)
1	July 27	Tommy Thompson Park, Lake Ontario, ON	Toronto and Region Conservation Authority (TRCA)	Boat Electrofishing	Live	Diploid	Male	13	1.02	14.7
2	July 28	Tommy Thompson Park, Lake Ontario, ON	DFO	Trammel Net	Live	Diploid	Male	14	0.97	10.2
3	Aug. 26	Jordan Harbour, Lake Ontario, ON	DFO	Trammel Net	Live	Diploid	Male	16 (or older)	1.05	16.7
4	Sept. 1	Toronto Islands, Lake Ontario, ON	TRCA	Boat Electrofishing	Live	Diploid	Male	11	0.91	10.6
5	Sept.1	Toronto Islands, Lake Ontario, ON	TRCA	Boat Electrofishing	Live	Diploid	Female	9	1.02	16.6
6	Sept. 2	Toronto Islands, Lake Ontario, ON	DFO	Boat Electrofishing	Live	Diploid	Male	13	0.89	9.1
7	Sept. 14	Bay of Quinte, Muscote Bay, Lake Ontario, ON	Commercial fisher	Trap Net	Live	Triploid	Female	13	1.04	12.7
8	Sept. 19	Lower Niagara River, ON	Recreational fisher	Dead on shore	Dead	Unknown	Unknown	10	0.95	8.1

However, seven more adult Grass Carp were caught in 2015 as a result of monitoring activities by DFO and other agencies or individuals (Table 3). In July 2015, two diploid male Grass Carp were caught within two days by the Toronto and Region Conservation Authority (TRCA) in a pond adjacent to, and previously (six months prior) connected to, Lake Ontario in Tommy Thompson Park, Toronto, Ontario, Canada (Table 3, Figure 1). These two fish were caught as part of a one-time 'fish rescue' operation for a construction project. In September 2015, three Grass Carp were caught within two days in an embayment in the Toronto Islands, Toronto, Ontario (Table 3, Figure 1). The first fish was captured by TRCA during regular sampling efforts as part of a fish tagging project, after which time, DFO, assisted by the Ontario Ministry of Natural Resources and Forestry and TRCA, initiated rapid response efforts that resulted in the capture of two additional Grass Carp. Two more Grass Carp were also captured in September 2015; one in the Bay of Quinte, Ontario by a commercial fisher and one found dead onshore in the lower Niagara River, Ontario by a recreational fisher (Table 3, Figure 1).

Overall, of the 2015 Lake Ontario captures, six were diploid, one was triploid (Bay of Quinte), and one was of unknown ploidy (Niagara River) (Table 3, Figure 1). These are the first confirmed records of diploid Grass Carp in Lake Ontario and the Canadian waters of the Great Lakes. Vertebral aging analyses, verified with at least one other structure, indicate the fish ranged from 9 to at least 16 years old. No evidence of recent spawning behaviour or activity was apparent in any of the diploid male fish. The diploid female fish was full of eggs in the process of reabsorption. Using oxygen isotope ratios of otoliths, analyses showed that ranges for all fish were consistent with those originating from aquaculture facilities (G. Whitledge, Southern Illinois University, pers. comm.). As of November 2015, additional analyses on life history were pending.

Analysis and Response

Considering the 2015 Grass Carp captures in Lake Ontario, the risk assessment authors reviewed the likelihood ranks and the ecological consequence ratings in the risk assessment document for Lake Ontario. Following the structure of the risk assessment document, the likelihood ranks for each of the risk elements and the ecological consequence ratings were reviewed separately for triploid and diploid Grass Carp. The authors based any changes to the likelihood ranks and ecological consequence ratings for Lake Ontario on data available for the Grass Carp captures as of November 2015. All tables and risk matrices for Lake Ontario from the risk assessment document, regardless of whether a change in rank or rating occurred, are included in this document. Changes are indicated in yellow highlighted bold type font within the tables and matrices.

Including the information on the recent Grass Carp captures in Lake Ontario did not change the likelihood of arrival, survival, spread, or the magnitude of ecological consequences for triploid or diploid Grass Carp in Lake Ontario (Tables 4, 5, 7, 10). With only one triploid Grass Carp captured no change in rank for any risk element, including magnitude of ecological consequences was deemed necessary. Therefore, the maximum rank of overall arrival and spread did not change (Table 8) and there was no change to the probability of occurrence (Table 9) or to the overall risk matrices (Figure 2).

Consideration of the recent Grass Carp capture information resulted in a few changes for diploid Grass Carp. Based on the definition used for arrival in the risk assessment document (i.e., the repeated detection of at least one Grass Carp in at least one part of the lake basin within any continuous 5-year period), diploid Grass Carp are now considered to have 'arrived' in Lake Ontario (Tables 4, 8, 9). While future captures of adult Grass Carp in Lake Ontario are possible, the age distribution of the 2015 captures are likely reflective of less restrictive management in

the past. Regulation of vectors and pathways for Grass Carp arrival has increased over time and those currently in place suggest managers should expect a low to moderate risk for future arrivals. Therefore, a change in likelihood of arrival was not needed.

However, the likelihood of establishment of diploid Grass Carp and certainty of data 5 years from November 2015 has changed, with an increase in rank from very unlikely to low, and a decreased level of certainty, from high to moderate (Table 6). This increase in rank is reflective of the diploid captures, which heightens the likelihood of establishment on a shorter time frame. A greater increase in rank was not warranted given the old age of the captured fish and that no young-of-year or juveniles were captured. The revised establishment rank at 5 years from November 2015 also changed the probability of introduction for diploid Grass Carp to Lake Ontario (Table 9).

Determining the probability of introduction involves comparison of ranks for arrival, survival, spread and establishment, and for Lake Ontario at 5 years from the baseline, the probability was found to be driven mainly by the likelihood of establishment (Cudmore et al. 2017). As such, the change in the likelihood of establishment for diploid Grass Carp also changed the probability of introduction at 5 years, which increased from very unlikely to low and the associated certainty changed from high to very low (Table 9). The ratings for the magnitude of ecological consequences for diploid Grass Carp did not change following the revised likelihood of establishment at 5 years, as the time to impact thresholds still fall within the same time steps considered for the risk assessment (Table 10). The overall risk for diploid Grass Carp remains low (green in matrix) at 5 years, although the certainty of data has decreased; no other changes in overall risk occurred (Figure 3). As of November 2015, additional analyses on life history were pending and the exact pathway(s) of arrival remain(s) unknown.

Likelihood of Arrival

Table 4. Overall revised likelihood of arrival rankings and certainties of data for Lake Ontario for triploid and diploid Grass Carp, 5, 10, 20, and 50 years from the baseline (i.e., November 2015). Arrival is defined as the repeated detection of at least one Grass Carp in at least one part of the lake basin (within any continuous 5-year period) and does not include the likelihood of Grass Carp entering one Great Lake from another; this is addressed in Spread. Overall arrival is the combination of physical connections, laker ballast and overall human-mediated release; the highest rank of these three elements is retained with the associated certainty of data. If a tied ranking occurs, the lowest associated certainty level is retained. If there is no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes. No changes occurred in rankings or certainties from original risk assessment document; however, diploid Grass Carp is now considered to have already arrived to Lake Ontario and is denoted by a yellow highlighted bold asterisk; arrival vector/pathway unknown. Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty of data (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH) (see Tables 1 and 2 in Cudmore et al. (2017) for definitions of rank and certainty of data).

Element	Triploid		Diploid	
	Rank	Cert	Rank	Cert
Physical Connections	5,10,20=Lo 50=M	Lo	5,10,20=Lo 50=M	Lo
Laker Ballast	VU	M	VU	M
Bait	VU	VLo	Lo	VLo
Stocking	5=Lo 10,20,50=M	Lo	5=VU 10,20,50=Lo	Lo
Trade	Lo	VLo	Lo	VLo
Overall Human-Mediated Release	5=Lo 10,20=M 50=H	5=VLo 10,20,50=Lo	Lo	VLo
OVERALL ARRIVAL (Combined Physical Connections, Laker Ballast, and Overall Human-mediated Release)	5=Lo 10,20,50=M	5=VLo 10,20,50=Lo	5,10,20=Lo 50=M*	5,10,20=VLo 50=Lo

Likelihood of Survival

Table 5. Revised likelihood of survival rankings and certainties of data for Lake Ontario for triploid and diploid Grass Carp, 5, 10, 20, and 50 years from the baseline (i.e., November 2015). Survival is defined as individuals that do not die upon arrival and adults living through winter months in the Great Lakes basin. If there is no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes. No changes occurred in rankings or certainties from original risk assessment document. Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty of data (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH) (see Tables 1 and 2 in Cudmore et al. (2017) for definitions of rank and certainty of data).

Time step (yr)	Triploid		Diploid	
	Rank	Cert	Rank	Cert
5	VLi	VH	VLi	VH
10	VLi	VH	VLi	VH
20	VLi	VH	VLi	VH
50	VLi	VH	VLi	VH

Likelihood of Establishment

*Table 6. Revised likelihood of establishment rankings and certainties of data for Lake Ontario for triploid and diploid Grass Carp, 5, 10, 20, and 50 years from the baseline (i.e., November 2015). Establishment is assessed independently of other elements in the introduction process and is evident by a self-sustaining population defined as the occurrence of individuals spawned within the Great Lakes basin subsequently reproducing. If there is no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes. Changes in rankings or certainties from the original risk assessment document are denoted in yellow highlighted **bold** font within the table. Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty of data (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH) (see Tables 1 and 2 in Cudmore et al. (2017) for definitions of rank and certainty of data). Note: Triploid Grass Carp are considered functionally sterile for management purposes and as such are ranked as VU with H certainty.*

Time step (yr)	Triploid		Diploid	
	Rank	Cert	Rank	Cert
5	VU	H	**Lo**	**M**
10	VU	H	VLi	M
20	VU	H	VLi	M
50	VU	H	VLi	M

Likelihood of Spread

Table 7. Revised likelihood of spread (between lakes, e.g., into Lake Superior from other lakes) rankings and certainties for Lake Ontario for triploid and diploid Grass Carp, 5, 10, 20, and 50 years from the baseline (i.e., November 2015). Spread is defined as the movement of individuals or expanding populations into new areas within the basin between lakes but not into the basin as this is arrival. Rankings mainly informed by the spread model used two of the most likely entrance points to the basin: the CAWS for Lake Michigan and Maumee River for Lake Erie (Currie et al. 2017). If there is no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes. No changes occurred in rankings or certainties from the original risk assessment document. Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty of data (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH) (see Tables 1 and 2 in Cudmore et al. (2017) for definitions of rank and certainty of data).

Time step (yr)	Triploid		Diploid	
	Rank	Cert	Rank	Cert
5	VU	M	VU	M
10	VU	M	Lo	M
20	Lo	M	Lo	M
50	Lo	M	Lo	M

Summary of Probability of Occurrence/Introduction

Table 8. Revised maximum rank of overall arrival and spread (Max(Arrival, Spread)) for Lake Ontario for triploid and diploid Grass Carp, 5, 10, 20, and 50 years from the baseline (i.e., November 2015). The certainty of data category associated with the maximum rank is retained; however, if tied ranks occur, the lowest certainty of data is retained. If no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes. No changes occurred in rankings or certainties from original risk assessment document; however, diploid Grass Carp is now considered to have already arrived to Lake Ontario and is denoted by a yellow highlighted bold asterisk; arrival vector/pathway unknown. Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty of data (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH) (see Tables 1 and 2 in Cudmore et al. (2017) for definitions of rank and certainty of data).

Element	Triploid		Diploid	
	Rank	Cert	Rank	Cert
Overall Arrival	5=Lo 10,20,50=M	5=VLo 10,20,50=Lo	5,10,20=Lo 50=M*	5,10,20=VLo 50=Lo
Spread	5,10=VU 20,50=Lo	M	5 =VU 10,20,50=Lo	M
Max(Arrival, Spread)	5=Lo 10,20,50=M	5=VLo 10,20,50=Lo	5,10,20=Lo 50=M*	5,10,20=VLo 50=Lo

*Table 9. Revised overall rankings and certainties for each lake for the probability of occurrence of triploid and the probability of introduction of diploid Grass Carp, 5, 10, 20, and 50 years from the baseline (i.e., November 2015). The minimum ranking of Max (Arrival, Spread) and Survival is retained for the probability of occurrence of triploid Grass Carp and the associated certainty; however, if tied ranks occur, the lowest certainty is retained. The minimum ranking of Max (Arrival, Spread), Survival, and Establishment is retained for the probability of introduction of diploid Grass Carp and the associated certainty; however, if tied ranks occur, the lowest certainty is retained. If there is no anticipated change in rankings and certainty over time, then years are not shown in the individual boxes. Changes in rankings or certainties from the original risk assessment document are denoted in yellow highlighted **bold** font within the table. Diploid Grass Carp is now considered to have already arrived to Lake Ontario and is denoted by a yellow highlighted bold asterisk; arrival vector/pathway unknown. Likelihood (Rank): Very Unlikely (VU), Low (Lo), Moderate (M), High (H), Very Likely (VLi); Certainty of data (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH) (see Tables 1 and 2 in Cudmore et al. (2017) for definitions of rank and certainty of data). NA=not applicable.*

Element	Triploid		Diploid	
	Rank	Cert	Rank	Cert
Max(Arrival, Spread)	5=Lo 10,20,50=M	5=VLo 10,20,50=Lo	5,10,20=Lo 50=M*	5,10,20=VLo 50=Lo
Survival	VLi	VH	VLi	VH
Establishment	VU	H	5=Lo 10,20,50=VLi	5=M 10,20,50=M
P(Occur)=Min [Max(Arrival, Spread),Survival]	5=Lo 10,20,50=M	5=VLo 10,20,50=Lo	NA	NA
P(Intro)=Min [Max(Arrival, Spread),Survival, Establishment]	NA	NA	**5**,10,20=Lo 50=M	**5**,10,20= VLo 50=Lo

Magnitude of Ecological Consequences

Table 10. Revised magnitude of lake-wide ecological consequences ratings and certainties for each lake for (A) triploid and (B) diploid Grass Carp, 5, 10, 20, and 50 years from the baseline (i.e., November 2015). Ratings were based on consequence thresholds and the probability of occurrence or introduction (see Table 3 in Cudmore et al. (2017) for description of ecological consequence ratings and associated consequence thresholds). If there is no anticipated change in ratings and certainty over time, then years are not shown in the individual boxes. No changes occurred in ratings or certainties from the original risk assessment document. Consequence Rating (Rank): Negligible (N), Low (Lo), Moderate (M), High (H), Extreme (E). Certainty of data (Cert.): Very Low (VLo), Low (Lo), Moderate (M), High (H), Very High (VH) (see Table 2 in Cudmore et al. (2017) for description of certainty of data categories).

Time step (yr)	Triploid		Diploid	
	Rank	Cert	Rank	Cert
5	N	M	N	Lo
10	N	M	N	Lo
20	N	M	Lo	Lo
50	N	M	E	Lo

Overall Risk Assessment

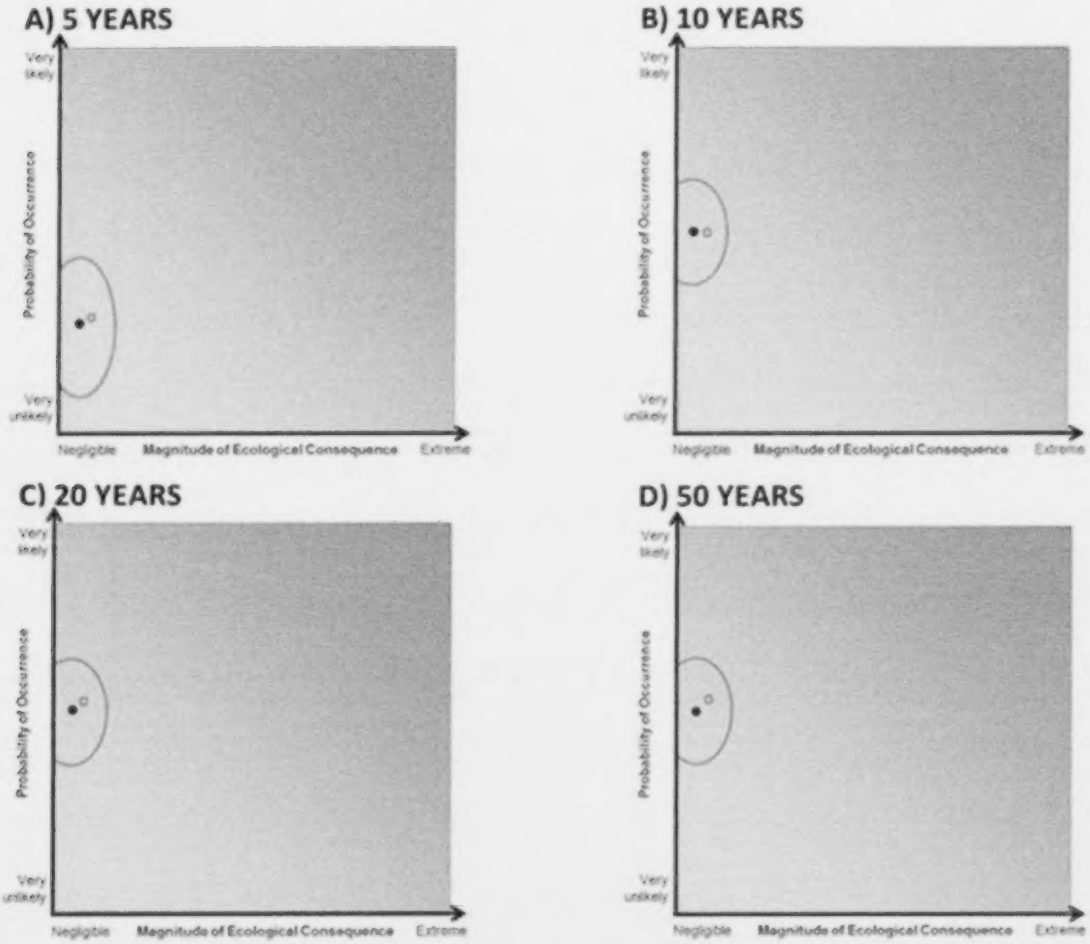

Figure 2. Revised probability of occurrence and magnitude of the ecological consequences for triploid Grass Carp over (A) 5 years, (B) 10 years, (C) 20 years and (D) 50 years from the baseline (i.e., November 2015) as a graphic representation to communicate risk for triploid Grass Carp. O=Lake Ontario; ellipses represent the amount of certainty of data around ranks with broader ellipses representing greater uncertainty of data. No changes occurred from the original risk assessment document. Overall Risk: Green = Low Risk; Yellow = Medium Risk; Orange = High Risk; Red = Extreme Risk (Modified from Mandrak et al. 2012).

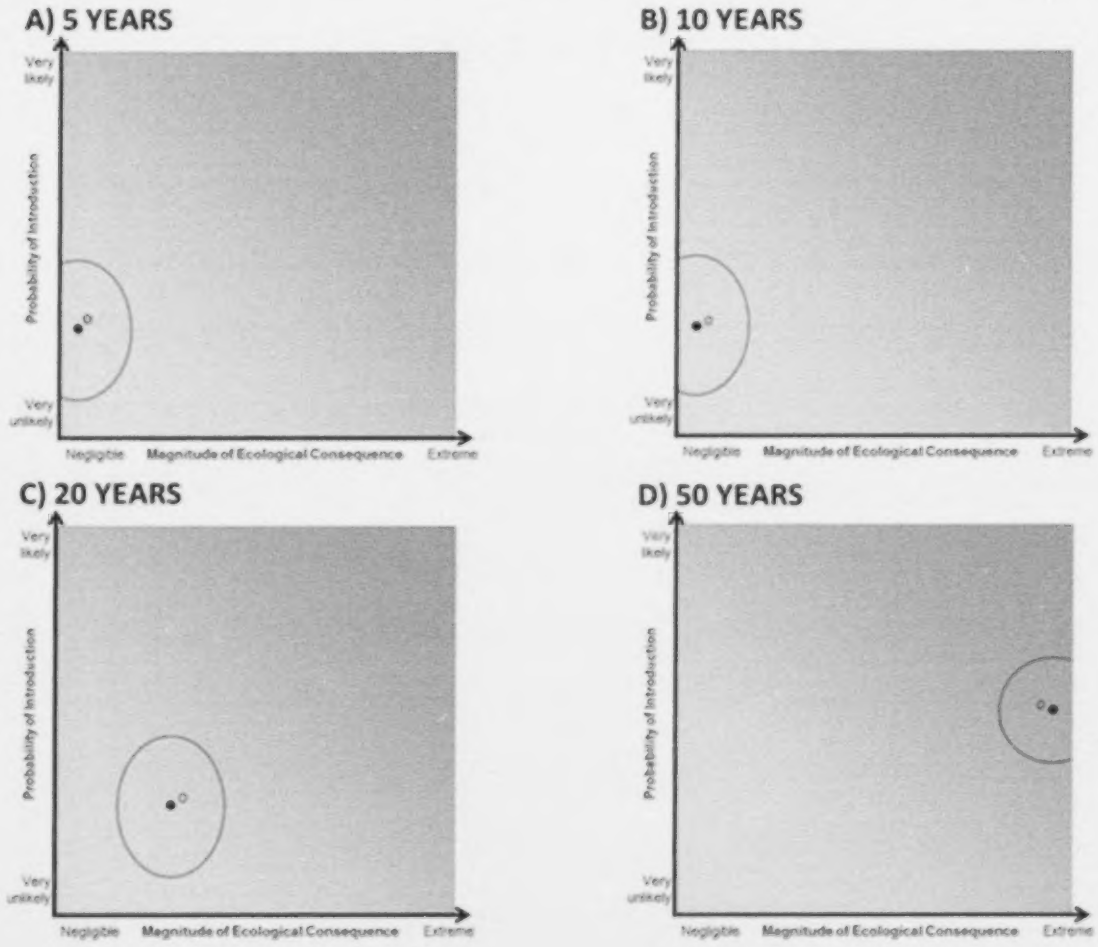

Figure 3. Revised probability of introduction and magnitude of the ecological consequences for diploid Grass Carp over (A) 5 years, (B) 10 years, (C) 20 years and (D) 50 years from the baseline (i.e., November 2015) as a graphic representation to communicate risk for diploid Grass Carp. O=Lake Ontario; ellipses represent the amount of certainty of data around ranks with broader ellipses representing greater uncertainty of data. Only the probability of introduction at 5 years and the associated certainty changed from very unlikely to low and from high to very low, respectively. Overall Risk: Green = Low Risk; Yellow = Medium Risk; Orange = High Risk; Red = Extreme Risk (Modified from Mandrak et al. 2012). Note: Grass Carp is considered to have already arrived to Lake Ontario.

Conclusions

Consideration of these new Grass Carp captures did not change the likelihood ranks of any of the risk assessment elements (arrival, survival, spread) nor any of the magnitude of ecological consequence ratings for triploid Grass Carp (Tables 4,5,7,10). Therefore the probability of occurrence (Table 9) and overall risk matrices (Figure 3) remain unchanged from the original risk assessment document. For diploid Grass Carp, the likelihood of establishment and its associated certainty of data changed at 5 years from the baseline of November 2015 (Table 6). In considering the six adult diploid Grass Carp captured or found, the likelihood was increased from very unlikely to low and certainty of data decreased from high to moderate. A greater increase in establishment rank at 5 years was not warranted given that all fish captured were at least 9 years old and no young-of-year or juveniles were captured. Reflecting the increased likelihood of establishment rank, the probability of introduction at 5 years from the November 2015 baseline also increased from very unlikely to low and certainty decreased from high to very low (Table 9). This increase in rank, and change in certainty, changed the overall risk matrix for diploid Grass Carp at 5 years (Figure 3). All other risk matrices for diploid Grass Carp remain unchanged from the original risk assessment document (Figure 3.) Furthermore, based on the definition of arrival used in the risk assessment, diploid Grass Carp is now considered to have arrived in Lake Ontario (Tables 4, 8 and 9). The uncertainty related to these ranks is captured in the associated certainties of data with each of the ranks and the sources of uncertainty remain consistent with those identified in the ecological risk assessment (Cudmore et al. 2017) and the associated Science Advisory Report (DFO 2017). Consideration of these captures through this Science Response process ensures that the risk assessment process delivers effective scientific advice for managers in a timely manner.

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(October 31, 2016)

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